United States
Department of
Agriculture

Forest Service

Southeastern Forest
Experiment Station

Research Paper
SE-279

Effects of Fenvalerate and Azinphosmethyl on Scale Insects and Their Natural Enemies in Loblolly Pine Seed Orchards

Stephen R. Clarke
Gary L. DeBarr
C. Wayne Berisford

THE AUTHORS

STEPHEN R. CLARKE and **GARY L. DeBARR** are Entomologist and Research Entomologist, respectively, U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Athens, GA; and **C. WAYNE BERISFORD** is Professor, Department of Entomology, University of Georgia, Athens, GA.

August 1990

Southeastern Forest Experiment Station
P.O. Box 2680
Asheville, North Carolina 28802

Effects of Fenvalerate and Azinphosmethyl on Scale Insects and Their Natural Enemies in Loblolly Pine Seed Orchards

Stephen R. Clarke, Gary L. DeBarr, and C. Wayne Berisford

ABSTRACT

Fenvalerate and azinphosmethyl were applied monthly by hydraulic sprayer during the 1984 and 1985 growing seasons to loblolly pines in a Bulloch County, GA, seed orchard. The orchard was infested with the striped pine scale, *Toumeyella pini* (King), a mealybug, *Oracella acuta* (Lobdell), and the woolly pine scale, *Pseudophilippia quaintancii* Cockerell. Azinphosmethyl caused significant female scale and mealybug mortality, but fenvalerate generally did not. Alternating applications of the two insecticides produced infestations intermediate between those treated only with azinphosmethyl or fenvalerate. More male scale insects emerged from shoots collected at this orchard from untreated trees than from shoots receiving insecticide applications. Parasitism of *T. pini* females was significantly higher on unsprayed trees only after the third insecticide applications in 1984. Predation of female *T. pini* was generally lowest on trees receiving azinphosmethyl applications. Populations of *T. pini* and *O. acuta* crashed in 1984, but this collapse was not related to insecticide applications.

Azinphosmethyl caused heavy mortality of both sexes of *T. pini* and *O. acuta* when individual branches were hand sprayed in a Toombs County, GA, seed orchard, while fenvalerate did not. Parasitism rates on untreated branches were significantly higher than rates on treated branches only at the end of the overwintering period. More males emerged from fenvalerate-treated shoots, and more parasitoids emerged from untreated shoots.

Ground applications of azinphosmethyl caused significant mortality of scale insects and mealybugs, whereas operational aerial applications did not. These results suggest that aerial application of insecticides, even those highly toxic to scale insects, are ineffective in controlling established scale insect infestations. Repeated use of fenvalerate in seed orchards increases the possibility of scale insect outbreaks.

Keywords: Pyrethroids, *Toumeyella pini*, *Oracella acuta*, *Pseudophilippia quaintancii*, secondary pests.

In recent years, pyrethroid insecticides have frequently replaced organophosphates for seed and cone insect control in southern pine seed orchards. Fenvalerate (a pyrethroid) and azinphosmethyl (an organophosphorous insecticide) have been registered by the U.S. Environmental Protection Agency for use in these control programs. Fenvalerate has a lower mammalian toxicity than azinphosmethyl; it therefore is safer to apply (Berisford and others 1985a, 1985b). However, some outbreaks of scale insects in southern pine seed orchards have been related to ground (Cameron 1989; Texas Forest Service 1980) and aerial (Nord and others 1985) application of pyrethroid insecticides. Severe scale insect infestations and the consequential sooty mold growth may hinder photosynthesis and reduce tree growth (Walstad and others 1973). Infestations of three scale insects and one mealybug have been observed in loblolly pine, *Pinus taeda* L., seed orchards in Georgia: the woolly pine scale, *Pseudophilippia quaintancii* Cockerell; the striped pine scale, *Toumeyella pini* (King); the pine tortoise scale, *T. parvicornis* (Cockerell); and a mealybug, *Oracella acuta* (Lobdell).

Pyrethroids are more toxic to some parasitoids than to their hosts (Coats and others 1979), and pyrethroids are less toxic than organophosphorous insecticides to crawlers of *T. pini* (Clarke and others 1988). Pyrethroid applications therefore may disrupt the host-natural enemy complex that maintains the scale insects at endemic levels, leading to scale insect outbreaks. Such insecticide-related outbreaks of scale insects are well documented. McClure (1977b) related resurgences in populations of the elongate hemlock scale, *Fiorinia externa* Ferris, to reductions in its parasitoids and predators following insecticide application. Luck and Dahlsten (1975) associated the use of malathion for mosquito control with outbreaks of the pine needle scale, *Chionaspis pinifoliae* (Fitch). Bartlett and Ortega (1952) discovered that the effects of DDT residues on a parasite led to increases in frosted scale, *Lecanium pruinosum* Coquillett, on walnut.

The objective of our study was to compare the effects of field applications of fenvalerate and azinphosmethyl on existing scale insect and mealybug populations and their natural enemies.

Materials and Methods

Whole-Tree Treatments

A 2-year study of the effects of fenvalerate and azinphosmethyl on scale insect infestations was undertaken at a loblolly pine seed orchard in Bulloch County, GA. Insecticides were applied monthly on an operational basis from April to August in 1982 and 1983 for seed and cone insect control. Infestations of *T. pini*, *O. acuta*, and *P. quaintancii* became apparent in 1982 after the first application of fenvalerate. Three adjacent 1.2-ha blocks established in 1978, 1979, and 1980, respectively, were heavily infested. Aerial applications on the six rows at the end of the oldest block were discontinued in June 1984. These rows comprised about one-third of the block. Nine clones with at least four ramets in this area were identified, and one ramet from each clone was randomly assigned to each of the four treatments: fenvalerate (Pydrin® 2.4 EC, Shell, Modesto, CA), azinphosmethyl (Guthion® 2L, Mobay Chemical, Kansas City, MO), alternating applications of fenvalerate and azinphosmethyl, and no insecticide (control). Insecticides were applied monthly from the ground with a high-volume hydraulic sprayer several days after the operational aerial insecticide application in the rest of the orchard. Fenvalerate was applied at a concentration of 0.025 percent (wt/wt) and azinphosmethyl at 0.18 percent (wt/wt). There were three applications in 1984 at monthly intervals beginning in June and five such applications in 1985 starting in April.

The remainder of the orchard was sprayed monthly from the air with insecticides at the registered rates from April to August. Fenvalerate was applied in April and August of 1984 and August 1985. Azinphosmethyl was used for all remaining treatments.

Sample shoots, which included the current growth cycle plus about 10 cm of the previous growth cycle (Greenwood 1980), were collected every 1 to 2 weeks from June 1984 to December 1985. Clones were randomly selected for each sampling date, four per date in 1984 and two per date in 1985. Sample shoots were taken from the middle to lower crown of one ramet of each clone per treatment. Trees were visually divided into directional quadrants, and one or two shoots were clipped from each quadrant with a pole pruner. One ramet of each of the selected clones in the aerially sprayed portion of the orchard was also sampled in 1985.

Shoots were examined under a dissecting microscope, and the female scale insects and mealybugs were counted and classified as "live," "dead," "parasitized," or "eaten by predators." Numbers of live females with eggs or crawlers, as well as the numbers and species of any predators, also were recorded. Empty mealybug resin cells were also counted.

Additional shoots were collected biweekly from three trees per treatment for rearing purposes. Infested shoots were placed in 19.5- by 8-cm mailing tubes with a 6- by 1.5-cm glass vial inserted in a hole drilled in the side. Two shoots were placed in each tube, with six tubes per treatment. Numbers and species of emerging natural enemies and male scale insects were recorded.

Individual-Branch Treatments

The short-term effects of fenvalerate and azinphosmethyl on established scale insect populations were examined at a loblolly pine seed orchard established in 1978 in Toombs County, GA. An outbreak of *T. pini* had begun in 1982 after initial aerial applications of fenvalerate and azinphosmethyl. Azinphosmethyl was applied aerially in May 1983 and in June and August 1984. It was applied four times from April to August in 1985 and five times from March to September in 1986. Azinphosmethyl was applied at 0.84 kg (AI)/ha in 1984 and 1985. At the other times, the recommended rate of 3.36 kg (AI)/ha was applied. The population collapsed in late 1984, but a resurgence occurred in mid-1985.

In November 1985, third-generation females were settling and males were present on the needles. One to three infested lower crown branches were then selected on 15 trees, and up to 8 infested shoots per branch were tagged. The branches were then randomly assigned one of three treatments: fenvalerate, azinphosmethyl, or no insecticide (control). The branches were selected so that there would be no spray drift between treatments. A total of 300 shoots was selected and about 100 shoots were assigned to each treatment. On November 8, insecticides were applied with a hand sprayer until needles and shoots were thoroughly wetted. Fenvalerate was applied at a concentration of 0.025 percent (wt/wt) and azinphosmethyl at 0.18 percent (wt/wt). Ten sample shoots per treatment were randomly selected and collected in early December, and 30 per treatment were collected in late March. Female *T. pini* were categorized as "live," "dead," "parasitized," or "eaten." Numbers and species of major predators were recorded, and female *O. acuta* were also counted when present.

Ten shoots per treatment with visible male populations were also collected on the first sample date, and 10 randomly selected needles per shoot were examined. Males were classified as "live," "dead," "parasitized," or "emerged."

In 1986, four to nine infested trees were treated on each of seven dates (table 1). Trees were selected in clusters to reduce environmental variation. As a result, numbers of trees treated varied somewhat by date. One lower crown branch per tree was sprayed with fenvalerate and one with azinphosmethyl. A third branch was designated as a "control." Insecticide dosages were the same as those in 1985. Insecticides were applied 1 to 2 weeks after operational aerial sprays, and shoot collections on those trees were stopped prior to the next aerial spray. This irregular schedule (table 1) was undertaken in an attempt to minimize the effects of the aerial applications on the results of our study, because unsprayed sections were not available as at the Bulloch County orchard.

Female scales and predators were counted and classified as described above. When male populations were present, 10 needles per shoot were randomly selected and the number and condition of the males were recorded. Additional infested shoots were collected from each treatment group and placed in mailing tubes for rearing. The numbers of males and parasitoids emerging were recorded.

Data Analysis

Analysis of variance for these experiments were run using PROC GLM (SAS 1982), and treatment means were separated with the Duncan option. Data from the first experiment were grouped by month (collections between treatments) and by year, while data from the second experiment were grouped by spray date or by collection date. Live scale insects per shoot in the first experiment were calculated as the average of the individual counts per shoot obtained on each tree, while percentages of mortality and parasitism were calculated as the ratio of total dead or parasitized on all shoots to the total living and dead. Similarly, branch averages or sums were used in the second experiment. Percentage data were subjected to an arc-sine square root transformation prior to analysis.

Results

Whole-Tree Treatments

Scale insect populations decreased substantially in both treated and untreated areas at the Bulloch County orchard during 1984. Although populations of the three species declined in all treatments, trees treated monthly with azinphosmethyl had consistently fewer females per shoot than trees receiving the other treatments (table 2). Significantly higher numbers of live females were found on fenvalerate-treated shoots than on control at two times: higher numbers of *T. pini* were found after the first spray and higher numbers of mealybugs after the third spray. Trees receiving the alternating treatments generally had infestations intermediate between the azinphosmethyl and fenvalerate treatments.

In 1984, parasitism increased to over 50 percent for *O. acuta* but was under 8 percent for *T. pini* (table 2). Parasitism of *P. quaintancii* was less than 2 percent. Significant differences were found only for *T. pini* after the third spray; unsprayed trees had a higher percentage of parasitism than sprayed trees. Predation on *T. pini* females was generally lowest on azinphosmethyl-treated trees, but significant differences between treatments were not found between the second and third sprays (table 2).

Woolly pine scale populations resurged in 1985, but there were no significant treatment differences in the numbers of females per shoot in the pre-spray collections or after the first spray (table 3). Significant differences in numbers of live females per shoot were found only in the collections after the second and the final insecticide applications. Significant differences in mortality of settled females appeared after the second spray, at the time when second-generation crawlers were settling, and those differences continued through the year. Numbers of females per shoot and female mortality generally were not significantly affected by fenvalerate treatments. Ground applications of azinphosmethyl significantly reduced female populations, while trees that received the aerial azinphosmethyl applications had infestation levels similar to those in fenvalerate and control treatments.

Toumeyella pini and *O. acuta* populations were too low to determine treatment effects in 1985.

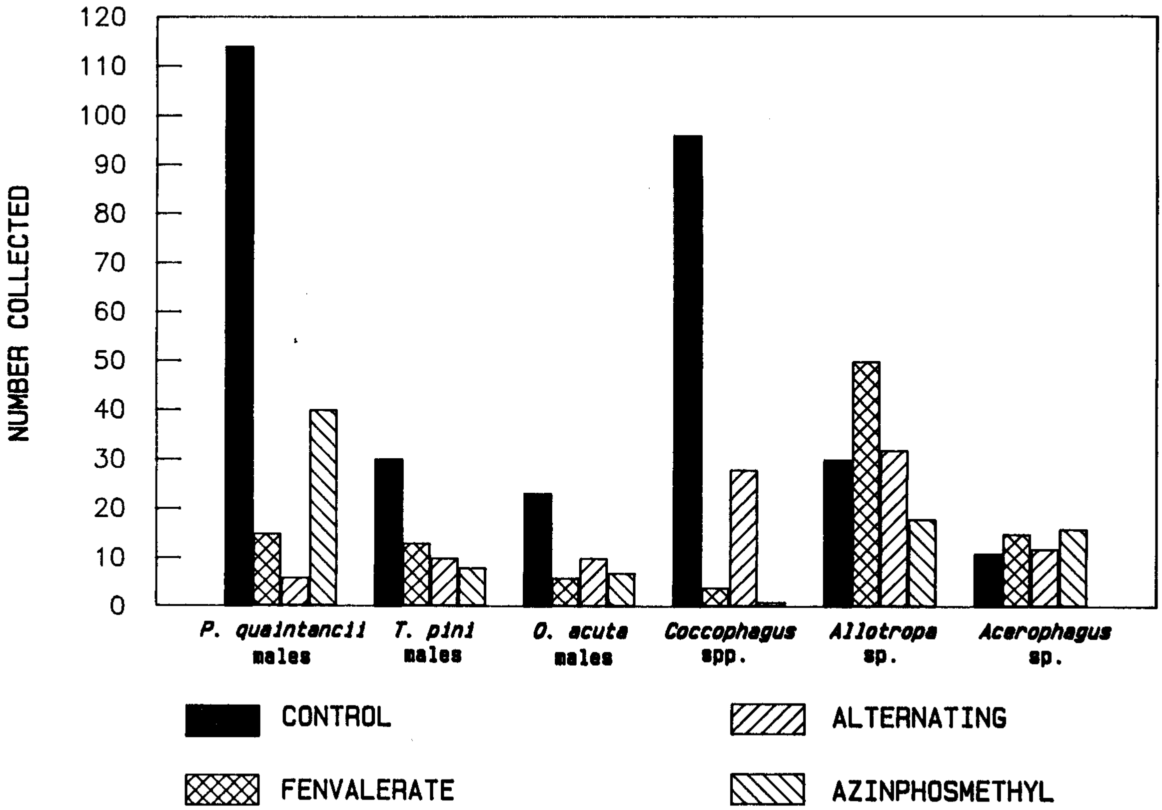

Figure 1 — Numbers of male scale insects and parasitoids emerging in rearing tubes from infested foliage collected at the Bulloch County, GA, seed orchard in 1984.

More males of all three scale species were reared from unsprayed than from sprayed shoots (fig. 1). Collections of *Coccophagus* spp. (Hymenoptera: Aphelinidae), parasitoids of *T. pini*, were also higher from control shoots. Numbers of a platygastrid, *Allotropa* sp., and an encyrtid, *Acerophagus* sp. — both hymenopterous parasitoids of *O. acuta* — were apparently not affected by any treatment.

Individual-Branch Treatments

In the Toombs County orchard, numbers of live *T. pini* females were lowest and mortality was highest on the azinphosmethyl-treated shoots. Female abundance usually did not differ significantly between the fenvalerate and control treatments (table 4). Parasitism of mature females was again generally low, rising to 55.1 percent only at the end of the overwintering period (table 4). Parasitism was lower on treated branches than on unsprayed branches at this time, but thereafter the parasitism rates differed significantly only once.

Numbers of live males on needles did not differ significantly between fenvalerate and control treatments, but the variability was high (table 5). Male mortality was highest in the azinphosmethyl treatments, while parasitism was significantly higher on control shoots than on sprayed shoots in the late summer. More *T. pini* males were collected from fenvalerate-treated shoots than from the other shoots, while more parasites emerged from males on unsprayed shoots (table 6).

Female *O. acuta* numbers again did not differ significantly between control and fenvalerate-treated shoots, while mortality was highest on branches sprayed with azinphosmethyl (table 7). Mortality increased in the control and azinphosmethyl treatments in the second half of July, but not in fenvalerate treatments. Parasitism was near zero in all treatments.

Discussion

Our results indicate that ground applications of azinphosmethyl cause significant increases in female scale insect mortality in southern pine seed orchards, while fenvalerate does not. These results reaffirm the importance of the relatively low toxicities of pyrethroids to loblolly pine scale insects in the onset and continuation of outbreaks. Azinphosmethyl and other organophosphorous insecticides have been shown to be more toxic than pyrethroids to *T. pini* crawlers (Clarke and others 1988). Bartlett and Ewart (1951) determined that parathion-induced outbreaks of the brown soft scale, *Coccus hesperidum* L., were related to the low susceptibility of the scales to the insecticide as well as to the suppression of natural enemies.

Though azinphosmethyl caused heavy mortality of both sexes, fenvalerate appeared more effective against *T. pini* males than females. Fewer males were collected from fenvalerate-treated trees than from untreated trees at the Bulloch County orchard (fig. 1). Although more males were generally collected from fenvalerate-treated infested needles at the Toombs County orchard (table 6), the higher total numbers of males and parasitoids collected from unsprayed needles suggest that fenvalerate caused male mortality as well as suppressed parasitism. Initial male populations (parasitized included) appeared similar in both treatments. Males may have been more sensitive to the insecticides than were the females, which were larger. Differences in mortality from insecticides between the sexes could also have been related to penetration. Females were immobile and usually covered with wax and honeydew, restricting insecticide penetration. Males were also covered by a waxy secretion called a test. However, cracks sometimes occurred, and the top and bottom covers separated at the end prior to emergence to allow the male to exit. These cracks and separations could increase the susceptibility of males to insecticides. The higher numbers of males collected from untreated foliage at the Bulloch County orchard (fig. 1) could also be attributed in part to insecticide-caused mortality. Insecticide-caused reductions in male populations may also affect female parasitism. Large populations of males can support and produce large numbers of parasites, many of which will also parasitize females (Clarke and others 1989).

The method of insecticide application appeared to be an important factor. Aerial applications may not provide as complete coverage of the foliage as ground applications. Barry and others (1984) found up to a 95-percent reduction in spray deposition in the lower crown as compared with the upper tip of the canopy with aerial spraying. In our studies, the ground application of fenvalerate probably contributed to increased male mortality by providing better coverage and canopy penetration. Azinphosmethyl, when applied as a drenching spray, caused significant female scale insect and mealybug mortality. However, operational aerial applications of azinphosmethyl did not appear to increase mature *P. quaintancii* female mortality in 1985, and the *T. pini* infestation at the Bulloch County orchard resurged in 1986 and remained high through 1987 despite monthly aerial applications. These results are consistent with earlier findings. Orr (1931) and Asquith (1949) found high-pressure drenching sprays of insecticides more effective than fogs or mists in controlling settled scale insects.

Differences in parasitism rates between treatments were generally nonsignificant. Rates were significantly higher for *T. pini* females on unsprayed shoots only during periods when aerial applications had ceased: the end of 1984 at the Bulloch County orchard and early 1986 after the overwintering period at the Toombs County orchard. Significantly higher parasitism for *T. pini* males occurred on unsprayed shoots at Toombs County in the late summer in 1986 after 1 1/2 months without aerial applications (table 5). These data indicate that ground applications of azinphosmethyl and fenvalerate reduce parasitoid activity. Croft and Brown (1975) found azinphosmethyl to be moderately toxic to parasitoids, while the literature review by Berisford and others (1985b) indicated that fenvalerate was highly toxic to many parasitoids. Fenvalerate did not reduce predation as did azinphosmethyl (table 2). Fenvalerate has been reported as less harmful to certain predator populations than to hosts or parasites (Croft and Whalon 1982; Shour and Crowder 1980).

Our observations and results indicate that aerial insecticide applications in seed orchards will normally have little effect on settled female scale insects, but they can result in lower resident natural enemy populations. Incomplete insecticide coverage may have significant impact on parasitoids. McClure (1977b) found that *Aspidiotiphagus citrinus* (Crawford), a parasitoid of *F. externa*, was almost eliminated, even when only half of an infested tree was sprayed with dimethoate 2E. Although our insecticide treatments suppressed natural enemies, they did not eliminate them. This result suggests that insecticide residues did not prevent migration from unsprayed shoots or trees to those nearby receiving insecticide applications. However, entire orchards or large blocks are generally sprayed in normal seed orchard operations. Such aerial applications can influence scale insect population dynamics (Clarke and others 1990), and may leave little opportunity for reestablishment of natural enemies from untreated areas. Future management strategies employing fenvalerate might include returning to ground applications in susceptible areas, increasing the interval between sprays, or leaving several rows or pockets of trees untreated to maintain enough parasites to keep scale insect populations at acceptable levels.

The population collapses of *T. pini* and *O. acuta* at the Bulloch County orchard and the lack of a resurgence in 1985 following fenvalerate applications indicate that environmental factors strongly influence the severity and duration of outbreaks of these pests. Insecticide applications alone probably cannot cause or maintain such outbreaks if other conditions are unfavorable. McClure (1977a) reported the detrimental effects of adverse edaphic conditions on *F. externa*, while Flanders (1970) described host "phenoimmunity," whereby environmental conditions rendered normally susceptible hosts temporarily immune to scale insect attacks.

The *T. pini* population reduction at the Toombs County orchard during the overwintering period indicates that different factors can interact to regulate populations. Numbers of females per shoot were higher in the fenvalerate treatment than in the control treatment in late 1985, but equal numbers were found in early 1986. Parasitism was greater in the control treatment, suggesting that other mortality factors compensated for the reduced parasitism in the fenvalerate treatments.

Our data reconfirm that fenvalerate should be used with caution for the control of seed and cone insects. If populations of scale insects are evident, fenvalerate use should be avoided. Even alternating applications of fenvalerate with other insecticides such as azinphos-methyl may prolong established infestations. Ideally, other integrated management systems for seed and cone insects should be sought. Chemicals, including other pyrethroids, included in these programs should be effective against the target insects but low in mammalian toxicity. The insecticide selected should also be more toxic to scale insects and less detrimental to their natural enemies than is fenvalerate.

The pesticides reported on and recommended here were registered for the use described at the time this manuscript was prepared. Since the registration of pesticides is under constant review of State and Federal authorities, a responsible State agency should be consulted as to the current status of these pesticides.

Acknowledgment

We authors thank Tom Coffey, Mike Cody, and Angie Hylton for their help with the data collection. A special thanks to Jo Hughey for her work in the preparation of the tables. We are grateful to Weyerhaeuser Co. and Continental Forest Investments for the use of their seed orchards, and to Shell Chemical Co. and Mobay Chemical Corp. for providing the insecticides. This work was supported by grants from the Georgia Forestry Commission, Shell Development Co., and Weyerhaeuser Co.

References

Asquith, Dean. 1949. Oils in dormant sprays to control European fruit lecanium and terrapin scale on peach. Journal of Economic Entomology 42(4):624-626.

Barry, John W.; Barber, Larry R.; Kenney, Patricia A. [and others]. 1984. Feasibility of aerial spraying of southern pine seed orchards. Southern Journal of Applied Forestry 8:127-131.

Bartlett, Blair; Ewart, W.H. 1951. Effect of parathion on parasites of *Coccus hesperidum*. Journal of Economic Entomology 44(3):344-346.

Bartlett, Blair R.; Ortega, J.C. 1952. Relation between natural enemies and DDT-induced increases in frosted scale and other pests of walnuts. Journal of Economic Entomology 45(5):783-785.

Berisford, Yvette C.; Goldner, Laurie L.; Hanula, James L. 1985a. Insecticide background statements: azinphosmethyl (Guthion®). Unpublished report submitted to USDA Forest Service, Forest Pest Management, Atlanta, GA. 166 pp.

Berisford, Yvette C.; Hanula, James L.; Cowie, Gail M. 1985b. Insecticide background statements: fenvalerate. Unpublished report submitted to USDA Forest Service, Forest Pest Management, Atlanta, GA. 162 pp.

Cameron, R.S. 1989. Promising new pesticides for seed and cone insect control in the southern United States. In: Proceedings of the 3d cone and seed insects working party conference; 1988 June 26-30; Victoria, BC, Canada: 193-202. Available from: Forestry Canada, Victoria, BC.

Clarke, Stephen R.; DeBarr, Gary L.; Berisford, C. Wayne. 1988. Differential susceptibility of *Toumeyella pini* (King) (Homoptera: Coccidae) to pyrethroid and organophosphate insecticides: a factor in outbreaks in southern pine seed orchards. Journal of Economic Entomology 81(5):1443-1445.

Clarke, Stephen R.; DeBarr, Gary L.; Berisford, C. Wayne. 1989. The life history of *Toumeyella pini* (King) (Homoptera:Coccidae) in loblolly pine seed orchards in Georgia. Canadian Entomologist 121:853-860.

Clarke, Stephen R.; DeBarr, Gary L.; Berisford, C. Wayne. 1990. Life history of *Oracella acuta* (Homoptera: Pseudococcidae) in loblolly pine seed orchards in Georgia. Environmental Entomology 19(1): 99-103.

Coats, S.A.; Coats, J.R.; Ellis, C.R. 1979. Selective toxicity of three synthetic pyrethroids to eight coccinellids, a eulophid parasitoid, and two pest chrysomelids. Environmental Entomology 8(4):720-722.

Croft, B.A.; Brown, A.W.A. 1975. Responses of arthropod natural enemies to insecticides. Annual Review of Entomology 20:285-335.

Croft, B.A.; Whalon, M.E. 1982. Selective toxicity of pyrethroid insecticides to arthropod natural enemies and pests of agricultural crops. Entomophaga 27(1):3-21.

Duncan, D.B. 1955. Multiple range and multiple *F* tests. Biometrics 11:1-42.

Flanders, S.E. 1970. Observations on host plant induced behavior of scale insects and their endoparasites. Canadian Entomologist 102(8):913-926.

Greenwood, Michael S. 1980. Reproductive development in loblolly pine: 1. The early development of male and female strobili in relation to the long shoot growth behavior. American Journal of Botany 67(10):1414-1422.

Luck, Robert F.; Dahlsten, Donald L. 1975. Natural decline of a pine needle scale (*Chionaspis pinifoliae* (Fitch)), outbreak at South Lake Tahoe, California following cessation of adult mosquito control with malathion. Ecology 56(4):893-904.

McClure, Mark S. 1977a. Dispersal of the scale *Fiorinia externa* (Homoptera: Diaspididae) and effects of edaphic factors on its establishment on hemlock. Environmental Entomology 6(4):539-534.

McClure, Mark S. 1977b. Resurgence of the scale, *Fiorinia externa* (Homoptera: Diaspididae), on hemlock following insecticide application. Environmental Entomology 6(3):480-484.

Nord, J.C.; DeBarr, G.L.; Barber, L.R. [and others]. 1985. Low-volume applications of azinphosmethyl, fenvalerate, and permethrin for control of coneworms (Lepidoptera: Pyralidae) and seed bugs (Hemiptera: Coreidae and Pentatomidae) in southern pine seed orchards. Journal of Economic Entomology 78(2):445-450.

Orr, Leslie W. 1931. Studies on the natural vs. artificial control of the pine tortoise scale. Tech. Bull. 79. St. Paul, MN: Minnesota Agricultural Experiment Station. 19 pp.

SAS Institute. 1987. SAS/STAT guide for personal computers, version 6 edition. Cary, NC: SAS Institute. 379 pp.

Shour, M.H.; Crowder, L.A. 1980. Effects of pyrethroid insecticides on the common green lacewing. Journal of Economic Entomology 73(2):306-309.

Texas Forest Service. 1980. Texas forests pest activity 1978-1979 and forest pest control section biennial report. Publication 121. College Station, TX: Texas Forest Service. 21 pp.

Walstad, John D.; Nielsen, David G.; Johnson, Norman E. 1973. Effect of the pine needle scale on photosynthesis of Scots pine. Forest Science 19(2):109-111.

Table 1—Dates of fenvalerate and azinphosmethyl individual-branch treatments and shoot collection schedule for the Toombs County, GA, seed orchard in 1986[1]

Branch spray date	Post-treatment collection date	Number of trees	Shoots collected per treatment per tree
May 5	June 2	9	4
May 16	June 2	8	4
	June 9	8	4
June 23	July 3	8	8
	July 14	5	8
	July 28	4	8
July 3	July 14	8	8
	July 28	4	8
July 14	July 28	4	8
July 28	August 19	5	4
August 7	August 19	5	4

[1]Aerial azinphosmethyl spray dates: March 26, May 1, June 10, August 21, and September 8.

Table 2—Mean numbers of live *Oracella acuta*, *Pseudophilippia quaintancii*, and *Toumeyella pini* females per shoot and percent parasitism and predation in 1984 on trees sprayed with fenvalerate or azinphosmethyl at the Bulloch County, GA, seed orchard[1]

	O. acuta		*P. quaintancii*	*T. pini*		
Treatment	Live females per shoot	Percent parasitism	Live females per shoot	Live females per shoot	Percent parasitism	Percent predation
			FIRST TO SECOND SPRAY (JUNE 13 - JULY 15)			
Fenvalerate	6.7a	26.7a	17.1a	30.4a	3.9a	0.6ab
Control	7.7a	37.9a	11.8ab	13.9b	2.5a	5.7ab
Alternating[2]	6.1a	26.0a	13.5ab	19.5ab	2.1a	5.8a
Azinphosmethyl	3.5a	36.2a	6.0b	8.8b	4.4a	0.2b
			SECOND TO THIRD SPRAY (JULY 16 - AUGUST 14)			
Fenvalerate	0.9a	47.2a	6.0a	16.1a	5.9a	14.0a
Control	0.9a	56.2a	7.5a	15.0a	5.7a	16.0a
Alternating[2]	0.7ab	46.7a	4.9a	10.8a	6.3a	10.9a
Azinphosmethyl	0.3b	63.0a	2.1b	3.4b	4.4a	11.6a
			AFTER THIRD SPRAY (AUGUST 15)			
Fenvalerate	0.31a	53.2a	1.6a	3.7a	4.5b	31.6a
Control	0.11bc	44.7a	1.6a	3.7a	7.1a	40.4a
Alternating[2]	0.21ab	54.5a	1.5a	2.7ab	4.7b	22.9b
Azinphosmethyl	0.06c	46.4a	0.5b	1.1b	4.4b	11.3c

Within periods and columns, means followed by the same letter do not differ significantly ($P = 0.05$; Duncan's [1955] multiple range test).

[1]Sample shoots were collected weekly or biweekly between spray dates.
[2]Fenvalerate sprayed in June and August; azinphosmethyl applied in July.

Table 3—Mean numbers of *Pseudophilippia quaintancii* females per shoot and female mortality on trees sprayed with fenvalerate or azinphosmethyl at the Bulloch County, GA, seed orchard in 1985

Treatment	Pre-spray	Collections made weekly or biweekly between— April 8-May 5	May 6-June 5	June 6-July 14	July 15-Aug. 14	Post-spray	1985 total
				LIVE FEMALES PER SHOOT			
Control	0.7a	6.7a	4.9b	6.9a	5.5a	2.6a	4.5ab
Fenvalerate	4.6a	0.6a	14.9a	7.0a	3.8a	2.2ab	6.3a
Alternating[1]	0.5a	4.1a	6.0b	4.1a	0.6a	0.8bc	2.7bc
Azinphosmethyl	0.3a	0.1a	4.0b	2.4a	1.3a	0.1c	1.3c
Aerial[2]	6.4	1.9	8.0	4.7	4.0	2.4	4.1
				PERCENT FEMALE MORTALITY			
Control	55.2a	48.6a	43.7ab	66.7ab	46.0a	57.0b	54.5bc
Fenvalerate	10.3a	44.2a	27.9b	48.8b	34.1a	59.1b	43.6c
Alternating[1]	16.7a	52.2a	43.5ab	54.4ab	71.3a	75.5a	60.9b
Azinphosmethyl	42.9a	50.0a	74.2a	74.7a	70.1a	92.2a	77.3a
Aerial[2]	33.3	91.2	53.6	54.9	39.3	55.9	61.7

Within columns, means followed by the same letter do not differ significantly ($P = 0.05$; Duncan's [1955] multiple range test).

[1]Fenvalerate and azinphosmethyl sprayed on alternate months.
[2]Included for the purpose of comparison.

Table 4—Mean number of live female *Toumeyella pini* per shoot and female mortality and parasitism on branches sprayed with fenvalerate or azinphosmethyl at the Toombs County, GA, seed orchard in late 1985 and 1986[1]

Treatment	Spray date								
	Nov. 8[2]	Nov. 8[3]	May 5	May 16	June 23	July 3	July 14	July 28	Aug. 7
	LIVE FEMALES PER SHOOT								
Control	11.8b	2.2a	17.7a	10.5a	7.8a	14.1a	34.6a	14.4a	15.4a
Fenvalerate	25.2a	1.6ab	6.6b	10.0a	6.8ab	14.8a	30.1a	10.2a	11.9a
Azinphosmethyl	4.7b	0.6b	4.9b	3.0b	3.8b	4.5b	3.8a	1.0b	4.1b
	PERCENT FEMALE MORTALITY								
Control	38.0b	78.3a	15.7b	27.0b	21.4b	26.4b	19.0b	28.3b	20.6b
Fenvalerate	45.4b	75.1a	23.8b	28.4b	22.7b	27.9b	14.6b	30.9b	38.2a
Azinphosmethyl	80.2a	83.5a	44.5a	71.6a	52.1a	72.5a	64.2a	84.4a	46.6a
	PERCENT PARASITIZED FEMALES								
Control	14.6a	55.1a	3.7a	4.7a	1.6a	0.6b	3.6a	1.1a	1.6a
Fenvalerate	11.5a	26.5b	1.1a	1.9a	2.2a	1.6ab	3.7a	3.1a	3.9a
Azinphosmethyl	6.5a	8.7c	1.7a	0.5a	6.4a	3.8a	24.3a	0.0a	13.9a

Within columns, means followed by the same letter do not differ significantly ($P = 0.05$; Duncan's [1955] multiple range test).

[1]One to three collections of shoots were made at approximately 10-day intervals after each spray. See table 1 for collection dates.
[2]Data from shoots collected November 28, 1985.
[3]Data from shoots collected March 24, 1986.

Table 5—Mean numbers of live and parasitized *Toumeyella pini* males and percent male mortality on branches sprayed with fenvalerate or azinphosmethyl at the Toombs County, GA, seed orchard in November 1985 and the summer of 1986

	Spray date					
Treatment	November 8[1]	June 23[2]	July 3[2]	July 14[2]	July 28[3]	August 7[3]
			LIVE MALES			
Control	32.9a	13.1a	19.1a	32.8a	8.0a	7.1ab
Fenvalerate	22.4ab	9.7ab	18.7a	11.2a	6.7a	18.2a
Azinphosmethyl	1.2b	2.3b	0.5b	2.9a	0.0b	0.8b
			PERCENT MALE MORTALITY			
Control	75.5b	54.9ab	44.2b	50.9b	66.7b	76.4b
Fenvalerate	74.6b	45.6b	46.1b	59.5b	70.6b	77.7b
Azinphosmethyl	95.4a	77.4a	96.3a	92.4a	99.2a	97.2a
			PERCENT MALES PARASITIZED			
Control	11.4a	1.2a	0.6a	0.3a	15.8a	12.3a
Fenvalerate	12.2a	0.0a	0.3a	2.9a	2.3b	4.3b
Azinphosmethyl	9.9a	0.0a	0.3a	0.1a	0.5b	1.8c

Within columns, means followed by the same letter do not differ significantly ($P = 0.05$; Duncan's [1955] multiple range test).

[1]Mean per 5 needles; needles collected November 28, 1985.
[2]Mean per 10 needles; needles collected July 28, 1986.
[3]Mean per 10 needles; needles collected August 19, 1986.

Table 6—Numbers of *Toumeyella pini* males and their *Coccophagus* spp. parasitoids reared from shoots treated with fenvalerate and azinphosmethyl at the Toombs County, GA, seed orchard in November 1985 and July and August 1986

Spray date	Collection date	Number of tubes per treatment	Treatment	*T. pini* males	*Coccophagus* spp.
			Fenvalerate	101	71
November 8	November 29	10	Control	8	153
			Azinphosmethyl	13	7
			Fenvalerate	96	78
July 14	August 7	9	Control	55	321
			Azinphosmethyl	6	28
			Fenvalerate	28	22
July 28	August 7	5	Control	18	60
			Azinphosmethyl	19	10
July 28	August 19	5	Fenvalerate	40	68
			Control	20	225
August 7	August 19	3	Fenvalerate	36	98
			Control	62	255

Table 7—Mean numbers of *Oracella acuta* females per shoot and percent mortality on branches sprayed with fenvalerate or azinphosmethyl at the Toombs County, GA, seed orchard in 1986

	Spray date[1]				
Treatment	June 23	July 3	July 14	July 28	August 7
	LIVE FEMALES PER SHOOT				
Control	1.6ab	1.9a	3.0a	6.7ab	5.0a
Fenvalerate	3.0a	2.4a	2.4a	9.6a	8.0a
Azinphosmethyl	0.8b	0.4b	1.0a	1.6b	6.4a
	PERCENT FEMALE MORTALITY				
Control	11.1b	1.7b	3.5a	11.1ab	15.4a
Fenvalerate	8.5b	5.3b	5.5a	4.1b	5.7a
Azinphosmethyl	35.6a	42.5a	17.5a	37.0a	32.4a

Within columns, means followed by the same letter do not differ significantly ($P = 0.05$; Duncan's [1955] multiple range test).

[1]See table 1 for collection dates.

Clarke, Stephen R.; DeBarr, Gary L.; Berisford, C. Wayne. 1990. Effects of fenvalerate and azinphosmethyl on scale insects and their natural enemies in loblolly pine seed orchards. Res. Pap. SE-279. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 14 pp.

Ground applications of azinphosmethyl caused significant mortality of the scale insects *Toumeyella pini* (King), *Pseudophilippia quaintancii* Cockerell, and *Oracella acuta* (Lobdell), whereas aerial applications did not. Fenvalerate applications generally did not cause significant mortality, and alternating applications of the two insecticides produced infestations intermediate between those treated only with azinphosmethyl or fenvalerate. Parasitism and predation rates were sometimes significantly lowered by insecticide applications.

Keywords: Pyrethroids, *Toumeyella pini*, *oracella acuta*, *Pseudophilippia quantancii*, secondary pests.

Clarke, Stephen R.; DeBarr, Gary L.; Berisford, C. Wayne. 1990. Effects of fenvalerate and azinphosmethyl on scale insects and their natural enemies in loblolly pine seed orchards. Res. Pap. SE-279. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 14 pp.

Ground applications of azinphosmethyl caused significant mortality of the scale insects *Toumeyella pini* (King), *Pseudophilippia quaintancii* Cockerell, and *Oracella acuta* (Lobdell), whereas aerial applications did not. Fenvalerate applications generally did not cause significant mortality, and alternating applications of the two insecticides produced infestations intermediate between those treated only with azinphosmethyl or fenvalerate. Parasitism and predation rates were sometimes significantly lowered by insecticide applications.

Keywords: Pyrethroids, *Toumeyella pini*, *oracella acuta*, *Pseudophilippia quantancii*, secondary pests.